Proceedings of the Ninth European Conference on Earthquake Engineering, Moscow 1990

APPLICATION OF HIGH VISCOUS DAMPER ON PIPING SYSTEM AND ISOLATION FLOOR SYSTEM.

Dr. Y. Ochi[1)], A. Kashiwazaki[1)], Dr. V. Kostarev[2)]

[1)] IHI Co. Ltd., Yokohama, Japan
[2)] CKTI-Vibroseism Ltd, Saint Petersburg, Russia

ABSTRACT

This paper deals with dynamic characteristics of new type high-viscous damper developed by CKTI-VIBROSEISM whose dynamic characteristic can be changed by the viscosity of liquid, the number and dimension of shells. The applicability of this high-viscous damper was very high by the vibration test of 6" three dimensional piping model and seismic Isolation Floor System using a shaking table. The large damping effect of CVS Damper have been shown through test and the experimental results agreed well with analytical one.

1. INTRODUCTION

Damping ratio is one of the most important parameters in the seismic design of the piping system or structures. It is a hypothetical factor used to represent the energy dissipation in piping systems or structures. To increase the damping ratio and reduce the seismic response positively, many types of device have been recently proposed.

Currently, piping supports in nuclear power plants include spring hangers, rigid supports (such as struts and frames) and snubbers. According to the requirement for design or operating conditions, rigid supports and snubbers are used to resist seismic and other dynamic loads. The location, type, and number of supports are determined by the nature of the dynamic loads, the system's operating conditions, physical characteristics, and allowable stress limits. The design criteria requires that rigid supports and snubbers remain essentially elastic under the imposed design loadings. Snubbers are used on hot piping systems to maintain flexibility under thermal expansion conditions and rigidity under dynamic excitation conditions. Several programs have been initiated to find more reliable support concepts, find ways to increase flexibility, and re-examine the seismic design bases (such as fundamental natural frequency of piping system). It is felt that the use of higher damping device in the piping design would reduce both the seismic response and the number of piping supports, and increase the flexibility and the reliability of the piping system.

On the other hand, one of the authors has been proceeded on the development of three-dimensional isolation floor system, employing seismic isolator composed of an air spring system and laminated rubber bearing(see fig. 1.1), [1]. The isolation system technology is to reduce the natural frequency of a structure to a low frequency (less than 1 Hz) apart from the predominant frequency of earthquake vibration, by supporting the structure by the isolator. As the result, response acceleration of the structure is reduced, but displacement relative to the non-isolated structure is apt to be lager. Therefore, the seismic isolator is used together with damper device to reduce relative displacement. Especially, in the partial isolation system such as the floor isolation, it is necessary not to reduce- the effective space on the floor, so that damper device with high damping of about 20% is adapted. It is required for the damper device of isolation floor system to have low stiffness not to affect the natural frequency of the system as well as damping. Moreover it is desirable to have no directional qualities in any horizontal direction.

From these points of view, high viscous damper using high viscous liquid was developed. The dynamic characteristics of this damper was investigated by the component test and applicability was verified by the vibration test of 3-dimensional piping model as well as isolation floor system.

2. MECHANISM OP HIGH VISCOUS DAMPER

Modern earthquake proof design is characterized by a tendency of wide using of mechanical and hydraulic snubbers, high viscous dampers and energy absorbers in piping systems, equipment and other structures.

Each of above mentioned devices has some positive and negative peculiarities. To overcome negative effects of used constructions, especially high prime and maintenance cost, low reliability, insufficient ability to compensate thermal displacements and absence of regulation possibilities, in Japan, USA, Germany and other countries different devices were developed. One of high viscous damper was developed in the Russia (CKTI-Vibroseism, Saint Petersburg).

The construction of CVS damper is protected with priority of European Patent Board N PCT/SU 89/00058 from 07.03.1989. The CVS damper consists of housing, piston, load and shells. The housing is filled with liquid with viscous range 100-10000 P.

Having constant dimensions of damper housing and piston and constant viscosity of liquid it is possible to change dynamic stiffness within a wide range by simply choosing number and dimensions of shells more than for two orders. It is done in order to achieve optimum damping in certain dynamic system even in under operational conditions of the equipment.

In fig. 2.1 is shown CVS dampers with external diameter 159 mm, 7 shells and viscosity of liquid 1600 P. Dynamic stiffness of damper consists of two parts - viscous and elastic with nonlinear function of frequency and linear from displacement on certain frequency.

3. TEST MODELS AND TEST METHODS

In order to verify the dynamic characteristics of the damper obtained by the component test, the vibration tests were carried out using the Three-dimensional large shaking table at IHI Earthquake-proof Engineering Laboratory.

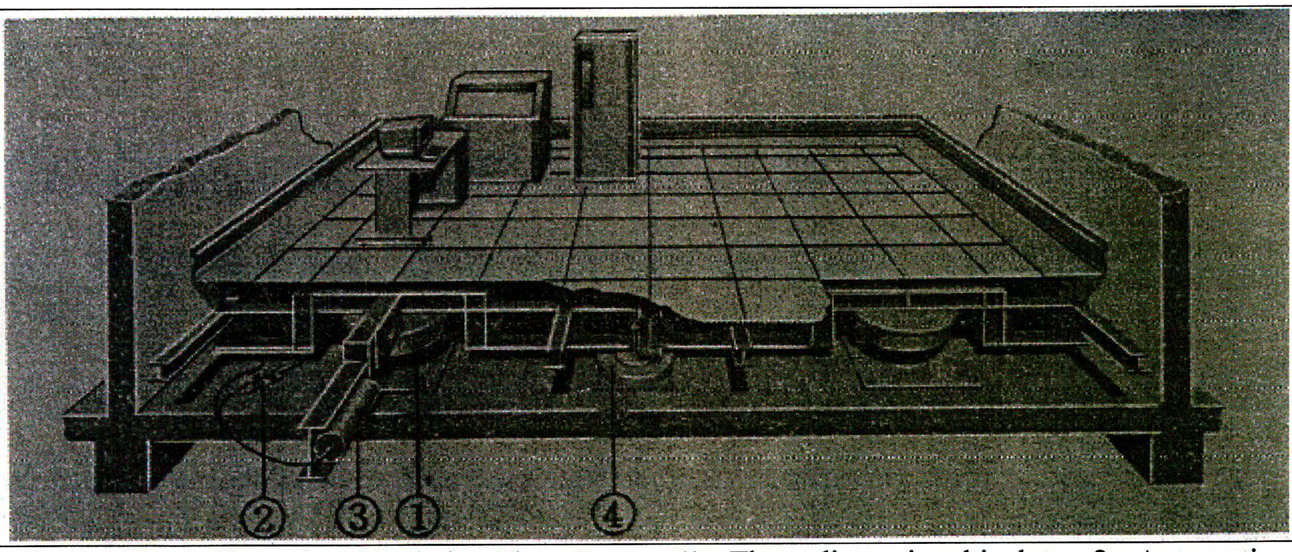

Fig. 1.1 Three-dimensional Isolation Floor System (1 - Three-dimensional isolator, 2 - Automatic level controller, 3 – Air Tank, 4 – Horizontal Damper)

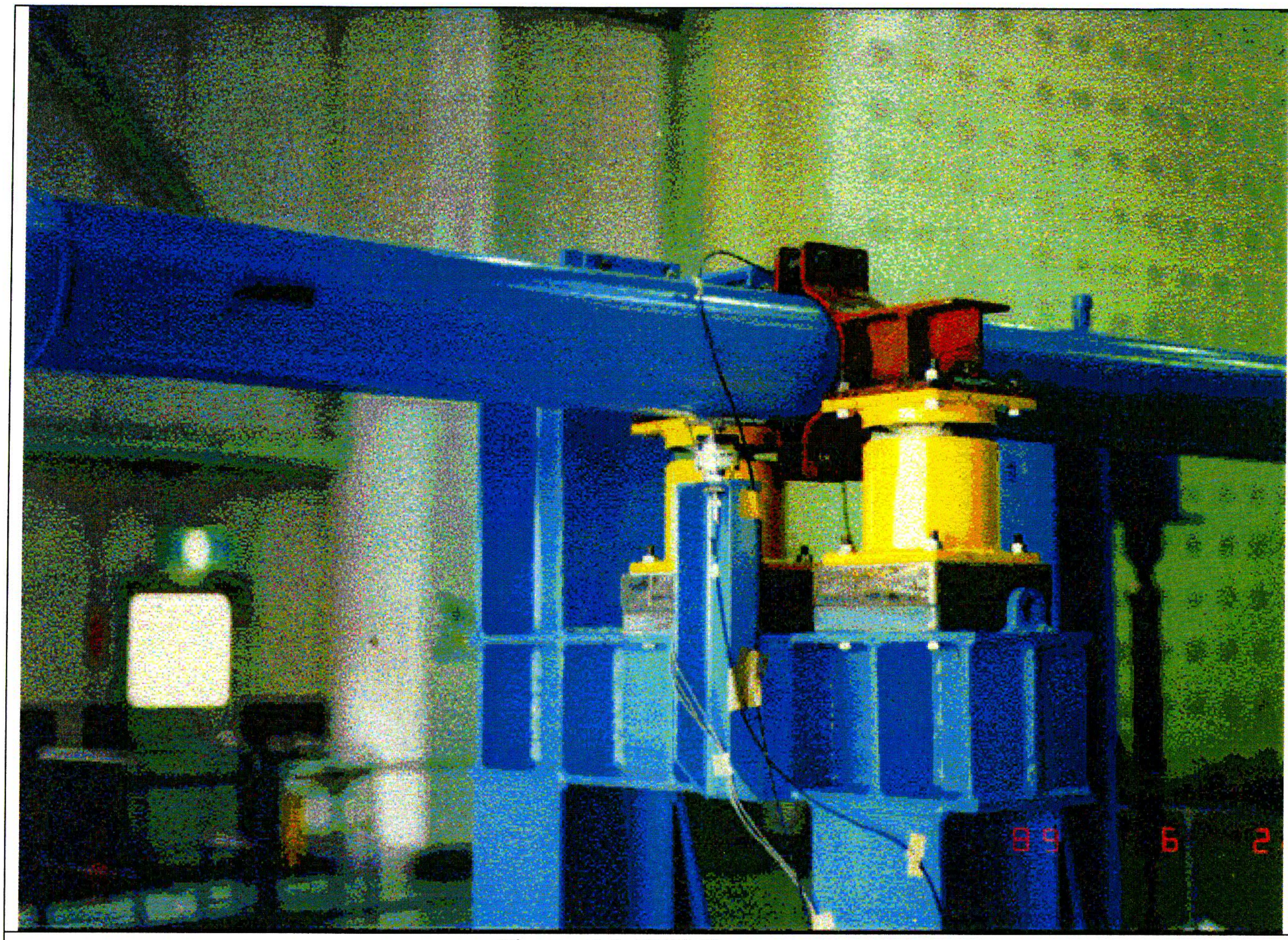

Figure 2.1 CVS Damper

3.1. PIPING MODEL TEST

The test was conducted using a 6 inch diameter, 7.1 mm thickness and 15m length 3-dimensional piping model as shown in fig.2.1, 3.1 and 3.2. In this test, damper location, number of dampers, the number of shells in the damper, and viscosity of liquid were substituted in order to clarify these affect of this damper parameter to dynamic characteristics of the piping system. The piping model was excited by the sinusoidal wave frequency sweep oscillation, El Centro-NS seismic wave and random, wave.

3.2. ISOLATION FLOOR SYSTEM

To examine the applicability of high viscous damper to the isolation floor system, shaking test was conducted for isolation floor model using two dampers.
The floor model used in the test is shown in fig1. The floor structure of 20 fonf was supported by four isolators. Each one of high viscous damper was installed at the middle point of each of the long two sides (see photo 3.3). And the number of shell in the high viscous damper was changed to find the satisfactory performance. The floor system was excited sinusoidal wave of frequency sweep oscillation and El Centro-NS seismic wave of floor response of 5^{th} stories building of natural frequency 2.7 Hz in horizontal direction.

4 TEST RESULTS

4.1. PIPING MODEL

The transfer function of the maximum response acceleration are compared in fig.4.1. These transfer functions were obtained from sinusoidal sweep excitation. This figure indicated that the response of piping system was drastically reduced by the installation of high viscous damper. Fig. 4.2. shows the relationship of first natural frequency and the magnification factor of first mode. The analytical results are also compared with the experimental ones. These analytical results are obtained by the complex eigen value analysis in which high viscous damper was modeled as a complex spring ($F=Ko(1+\eta)$) based on the component test results. The analytical results agree well with the experimental ones. The increase of the number of shells make it possible to decrease the piping response and to increase the natural frequency. But excess of shell number, viscosity or number of dampers make an adverse results (only increase the natural frequency). The dynamic characteristics of the piping model is sensitive to the shell number, liquid viscosity and the number of damper because the piping system is relatively flexible. It is indicated that there is an optimum combination of viscosity of liquid, number of shells or dampers for the piping configuration, piping diameter and piping thickness.

From acceleration time histories for each test cases the relationships between max. response acceleration and max. input one are shown in fig. 4.3. The max response acceleration is reduced to 2/5 in case that only one damper with 7 shells and liquid of viscosity 1600 poise is located at node 19.

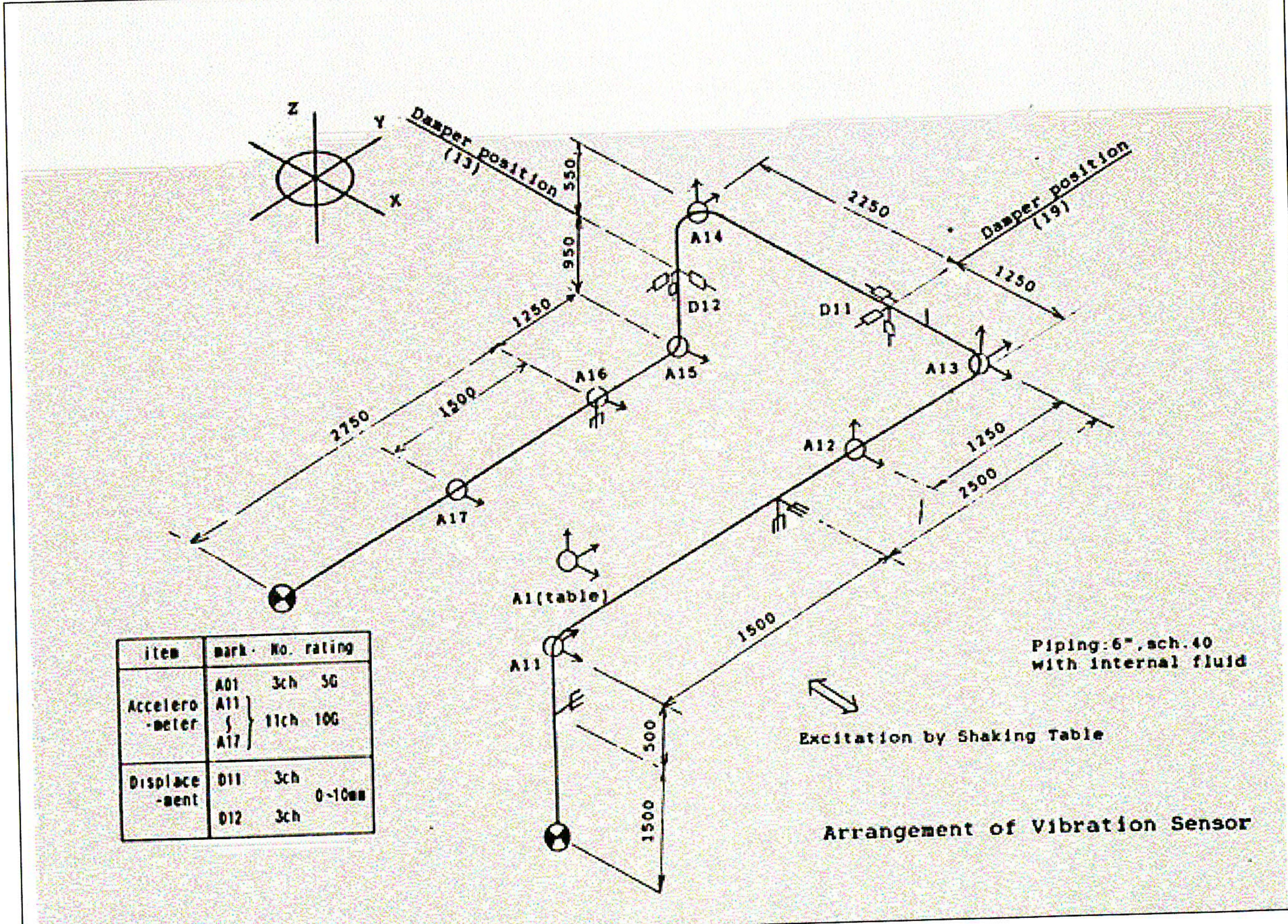

Figure 3.1 Arrangement of Vibration Sensor

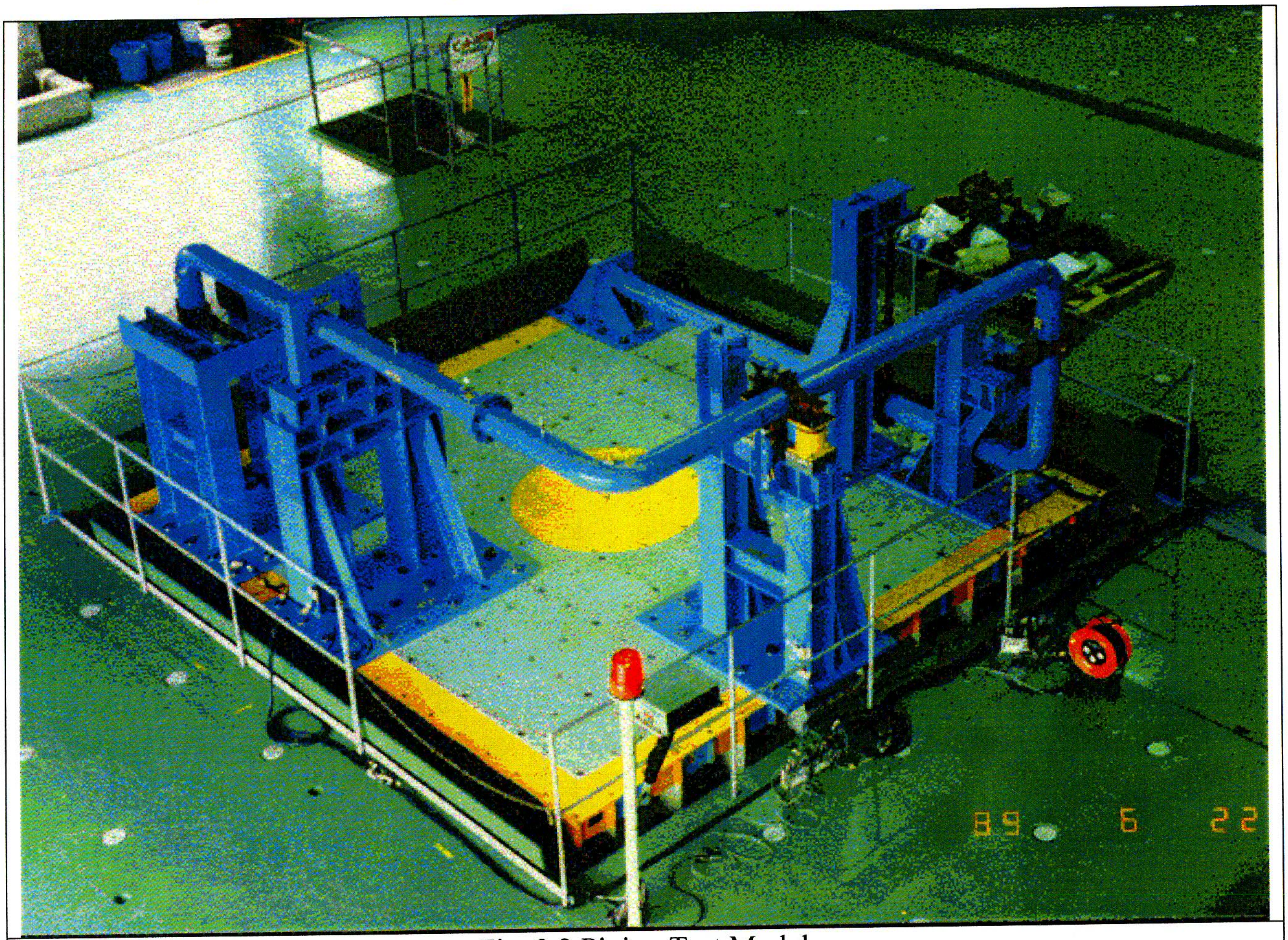

Fig. 3.2 Piping Test Model

Fig. 3.3 CVS Damper

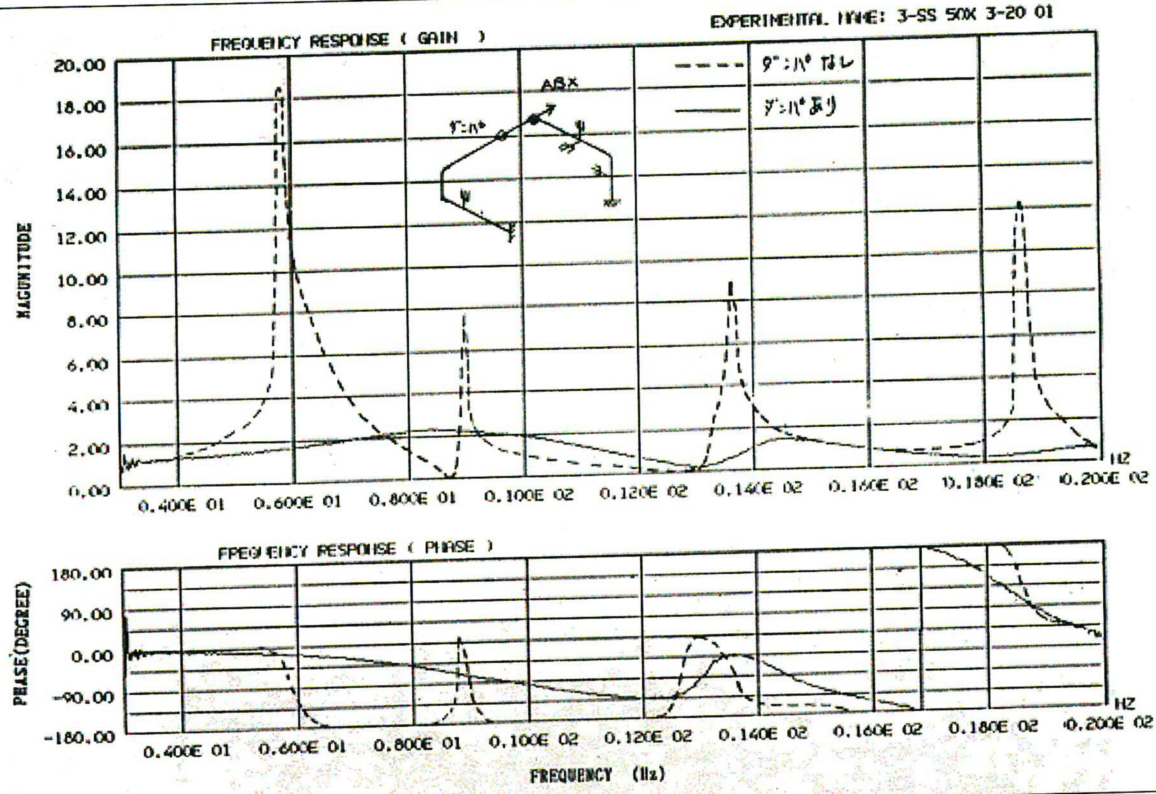

Fig. 4.1 Transfer Function (A13X/A01X) 19: (3-1600)x1

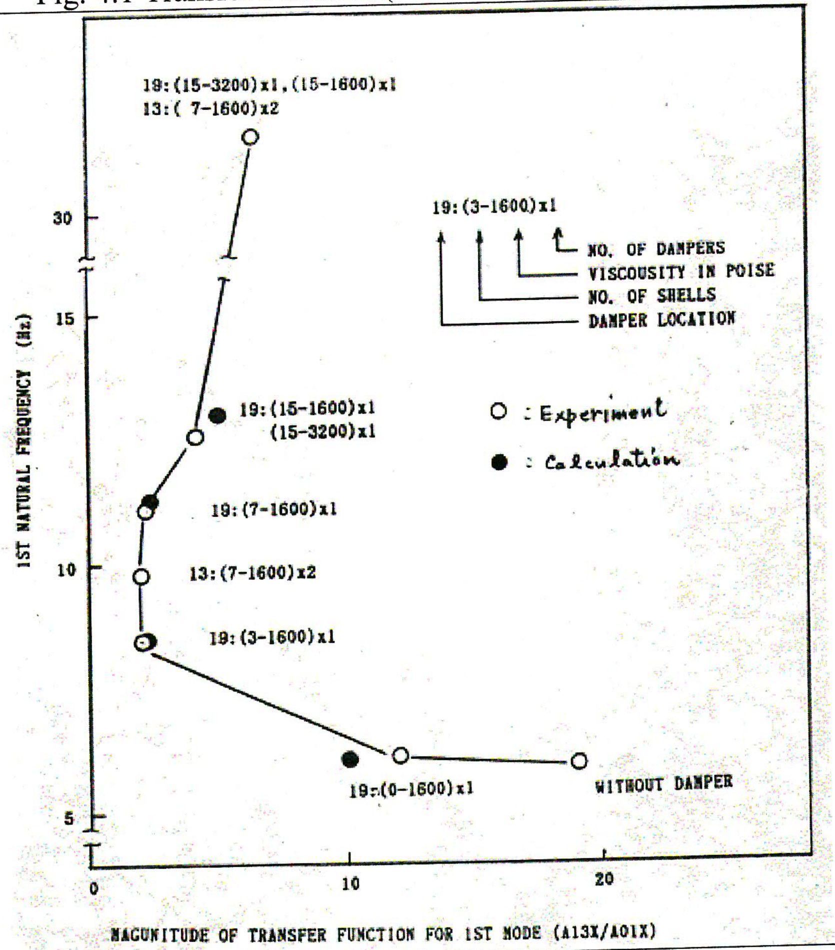

Fig. 4.2 Relationship between 1st natural frequency and magnitude of transfer function for 1st mode.

SYMBOL	DAMPER POINT	NO. OF DAMPER	NO. OF SHELL	VISCOSITY (POISE)
○	WITHOUT DAMPER			
□	19	1	3	1600
△	19	1	7	1600
▽	19	1	0	1600
◇	19 19	1 1	15 15	1600 3200
△	13	2	7	1600
▲	13 19	2 1 1	7 15 15	1600 1600 3200

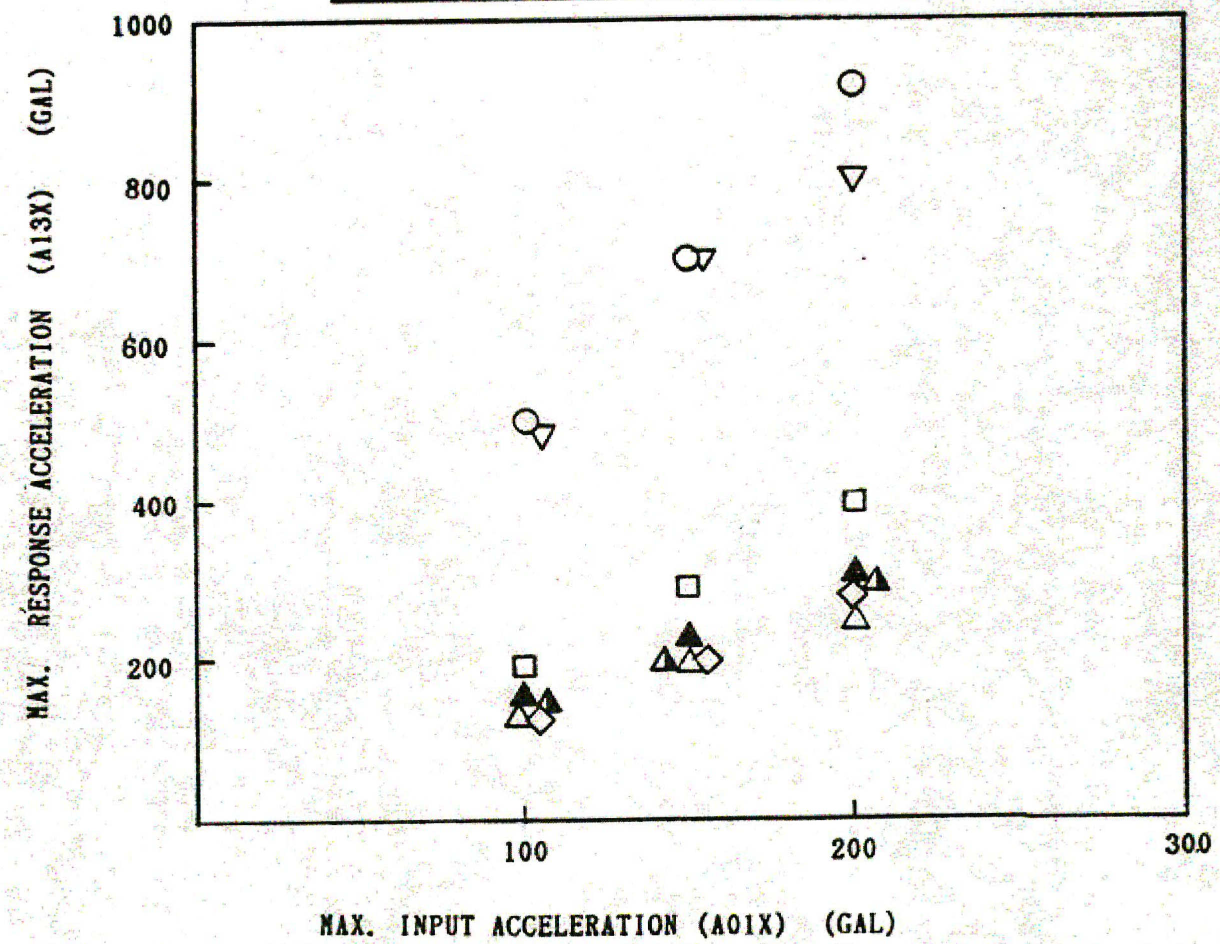

Fig. 4.3 Relationship between max. input acceleration and max. response acceleration. (MTM-Wave)

4.2. ISOLATION FLOOR

The transfer function of response acceleration to input one obtained from sinusoidal sweep excitation tests are shown in fig.4.4. As number of shell is increased, the magnification factor is decreased, but the resonant frequency does not change so much. So, high viscous damper can obtain-high damping force with slight increase of stiffness of the system.

The test results for EL Centro-NS floor response wave excitation is indicated table 1. Here, the critical damping ratio is the equivalent ones that are determined in comparison with the relative displacement response spectrum. And response waves of the model with high viscous dampers of 15 shells are shown in fig.4.5. The performance of the reduction of relative displacement is also improved with increasing number of shells. In the case of 15 shells, the critical damping ratio of the system reached to 14%. Installation of four high viscous dampers or increase of shell make it possible that damping ratio of isolation floor attain to more than 20%, which is required for the isolation floor system.

From these test results, it is concluded that this high viscous damper can be adapted as a horizontal damper device for isolation floor system.

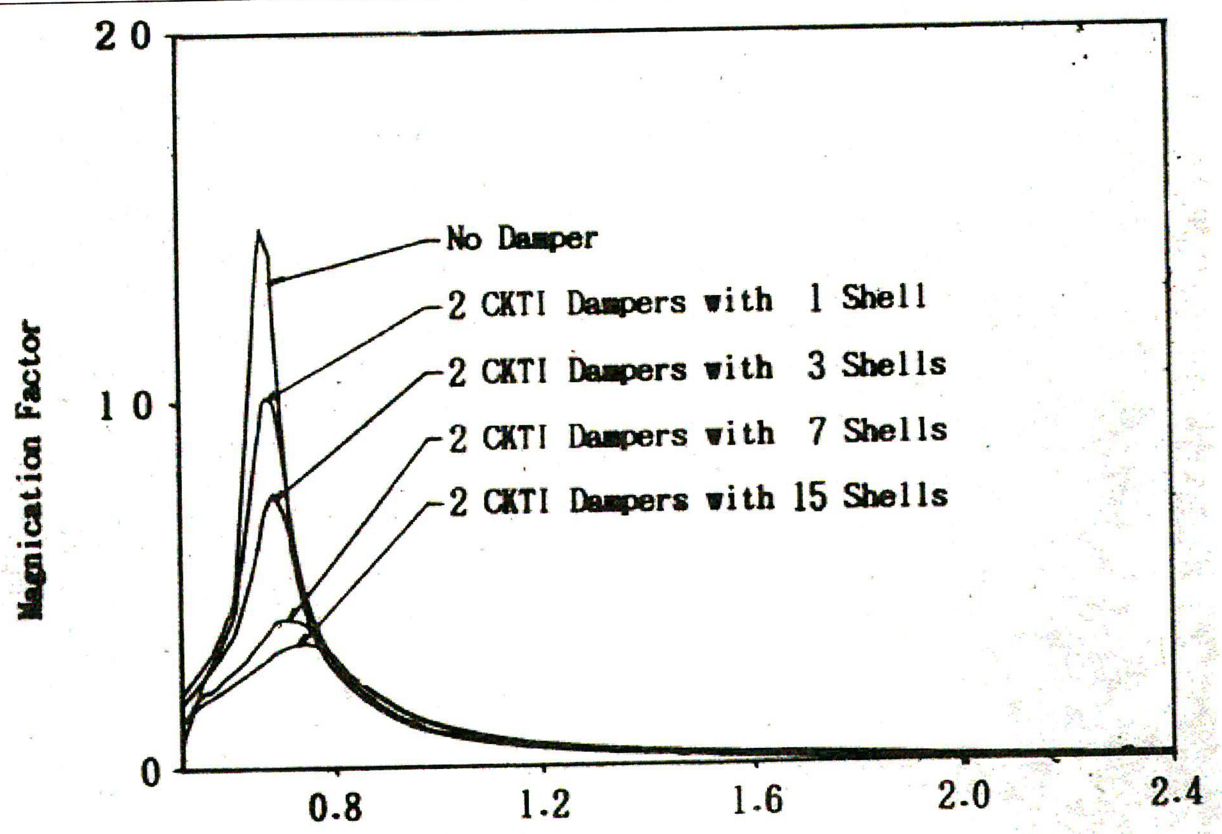

Fig. 4.4 Transfer Function by Sinusoidal Sweep Excitation (Input Displacement of 5 mm)

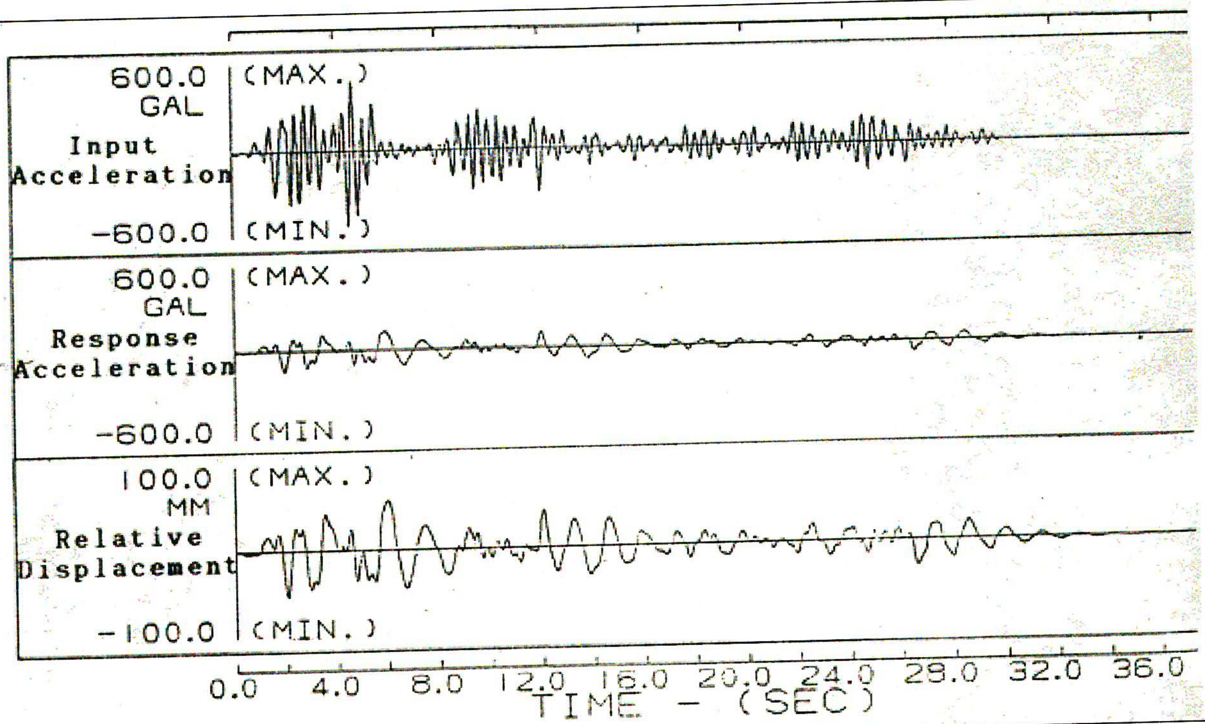

Fig. 4.5 Responses Excited by the El Centro-NS Flor Response Wave (Two CVS Dampers with 15 shells)

Table 1. Test Results Excited by the El Centro-NS Floor Response Wave

		Max. Input Acc.	Max. Response Acc.	Max. Relative Disp.	Crit. Damping Ratio
No Damper		499 gal	161 gal	83 mm	3%
Two CVS Dampers	1 Shell	530 gal	141 gal	71 mm	5%
	3 Shells	5 1 5 gal	1 3 9 gal	69 mm	5%
	7 Shells	5 1 5 gal	134 gal	61 mm	11%
	15 Shells	5 1 9 gal	1 4 3 gal	59 mm	14%

5. CONCLUSIONS

The damping effect of the high viscous damper have been shown through the vibration test results of the piping model and the isolation floor system. This newly developed damper have large damping effect. They are helpful to reduce the seismic response of piping systems or relative displacement of the isolation floor system. The damping effects of this damper is linear to displacements by certain frequency, so, it is easy to calculate the seismic response of structures supported this damper. Moreover, this damper has applicability to other components or structures such. as steel flame structures, bridges, press machines or engines.

6. REFERENCE

[1] KASHIWAZAKI, A., .TANAKA, M. and TOKUDA, N.,: Shaking Test of Seismic Isolation Floor System by Using 3-dimensional Isolator, 9WCEE (1988), Proceedings-Vol.7, pp845.